PATENT SPECIFICATION (11) 1 326 665

DRAWINGS ATTACHED

(21) Application No. 35588/71 (22) Filed 29 July 1971 (19)
(31) Convention Application No. P20 37 755.3
(32) Filed 30 July 1970 in
(33) Germany (DT)
(44) Complete Specification published 15 Aug. 1973
(51) International Classification G07D 7/00
(52) Index at acceptance
G1A 211 212 21X 21Y 247 248 269 357 358 369 400 402 407 425 426 428 42Y 435 436 438 43Y 447 448 457 458 461 463 464 467 46Y 471 475 478 481 49X 521 52Y 530 53Y 552 553 55Y 627 656 712

(72) Inventor ROBERT WILDENRATH

1 326 665

n. W. aufgelossen 26.12.73

(54) METHOD OF AND APPARATUS FOR TESTING THE AUTHENTICITY OF PIECES OF PAPER

(71) We, NATIONAL REJECTORS INC. G.m.b.H., a German Body Corporate, of 215, Buxtehude, Zum Fruchthof 6, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a method of and apparatus for testing the authenticity of pieces of paper, particularly but not exclusively bank-notes which contain fluorescent material, for example particles or fibres.

In known processes for testing the authenticity of pieces of paper, such as bank-notes, the pieces of paper to be tested are checked with respect to the printing inks used and to the design printed on their surfaces, with reference to a standard piece of paper. Checks have also been made on the watermark in the paper, a safety thread incorporated in the paper, or the type of paper used.

All the above mentioned processes, however, are unsatisfactory as regards their ability to prevent fraud. It has been found that falsifications are most likely to be detected if the pieces of paper are tested with respect to features which have been introduced into the body of the paper during production of the paper used, such features being distinct and distinguishable from features subsequently added to the individual piece of paper. For example German bank-notes have been printed for some time on paper with fluorescent fibres embedded therein, the fluorescent fibres in this case being mainly of a thickness only a little less than that of the paper used.

It is the aim of the present invention to provide for testing to establish the presence of such fluorescent material incorporated in the paper, and to distinguish the fluorescent material from fluorescent material subsequently applied to the piece of paper.

Thus, according to the present invention, there is provided a method of testing the authenticity of pieces of paper containing fluorescent material, in which the paper is moved past a light source the radiation of which excites the fluorescent particles, and the fluorescence radiation emanating on that side of the paper which is averted from the the light source is measured by means of a photo-receiver which is sensitive only to that radiation, the result of the test being indicated by the output of the photo-receiver.

It is possible to distinguish between an imprinted fluorescence layer and fluorescent material distributed in the volume of paper. If, for instance, the imprinted layer is situated on that side of the piece of paper which faces towards the light source, then the exciting radiation may well excite the fluorescent material to emit the fluorescence spectrum, but this radiation does not reach the photo-receiver situated on the other side because it is essentially absorbed by the material of the paper. If, on the other hand, the imprinted layer is present on that side of the paper away from the light source, then the exciting radiation emitted from the light source does not effectively excite the applied fluorescent material to emit the fluorescence radiation because it is absorbed in the paper layer. In neither case, therefore, is the photo-receiver excited to produce an indicative signal.

With the fluorescent material embedded in the paper and of thickness comparable to that of the paper, a portion of the exciting radiation emitted from the light source is likewise absorbed but the intensity of radiation impinging on the fluorescent ma-

[*Price 25p*]

terial suffices to excite the material to fluorescence as there is only a thin layer of paper covering the fluorescent material on each side, which thin layer absorbs the fluorescence radiation to only a minor extent so that the photo-receiver registers the radiation and produces an indicative signal.

As the photo-receiver is responsive only to the spectrum of emission emitted from the fluorescent material, the measuring is not affected by the exciting radiation, the wave length of which is shorter than that of the fluorescence radiation. It is to be noted here that fluorescent substances having a relatively narow spectral band of excitation and emission are comonly chosen for use.

In order to increase the sensitivity of the process, the fluorescence radiation emanating from that side of the paper which faces the light source is preferably also measured by means of a photo-receiver which is sensitive only to that particular radiation to provide a further indicative output. This is advantageous because the thickness of the fluorescent material is not uniform and some of the material may be situated more closely beneath the illuminated surface and some more closely beneath the other surface.

In order to perceive cracks or seams which may easily occur when fluorescent material is applied to the paper after it has been produced, provision is preferably made for the radiation passing through the paper to be measured by means of a photo-receiver which is sensitive only to that exciting radiation and the size of the associated signals is additionally taken into consideration when accepting or rejecting the piece of paper. When a crack or inaccurate seam is present the intensity of the light passing through is high, so that the resulting signal will have a considerable amplitude level or show a high pulse count.

In order to increase still further the effectiveness of the testing operation, the signals arising from the fluorescence radiation emanating from that side of the paper which is averted from the light source may be counted, and the piece of paper is accepted when a certain minimum number of pulses is reached. In this way the test cannot be deceived by the presence of a single fluorescent particle introduced into the paper. As during production of the paper the fluorescent material is uniformly dispersed in the paper a uniform distribution of fluorescent material can be taken to be present over the area of the piece of paper.

In the movement of the paper past the light source, several portions of the material are effective one after another to emit a fluorescence radiation so that a minimum number of signals may be determined to be characteristic for each type of paper for the purpose of the testing of the paper. The piece of paper under test is not acceptable if this minimum number is not reached.

The examination procedure may be further improved by basing the acceptance of the piece of paper upon the coincident occurrence of the signals resulting from the fluorescence radiations emanating from both sides of the paper. Distinction between embedded fluorescent material and subsequently applied fluorescent material is achieved with greater assurance if the fluorescence radiations are measured as they are emitted simultaneously from both sides of the piece of paper.

Provision is also desirably made for simultaneously detecting the exciting radiation through the piece of paper to test the transparecency of the paper in order to recognize a lacking watermark, a missing safety thread, a wrong density of the paper or spots of applied adhesives in the paper. For this purpose the signals resulting from the exciting radiation passing through are discriminated, and rejection of the piece of paper is effected when the lower threshold is not reached or when the upper threshold is exceeded.

The characteristic features of the fluorescent substances include not only the absorption and emission spectra but also the duration of afterglow. The excitation and registration of the fluorescence radiation may therefore be done simultaneously or at times spaced by an interval. In the latter case, additional use may be made of the afterglow period as a parameter of testing.

According to another aspect of the invention there is provided apparatus for testing the authenticity of pieces of paper containing fluorescent material with the aid of a light source the radiation of which excites the fluorescent particles, and including means for moving the paper spread-out in a plane past the light source, the light source and a photo-receiver sensitive to the fluorescence radiation emitted from the particles being arranged on opposite sides of the plane. To increase the accuracy in testing, another photo-receiver sensitive to the emitted fluorescence radiation is preferably arranged on the side of the plaane on which the light source is located. The testing apparatus may further include a photo-receiver which is sensitive only to the exciting radiation, arranged on the other side of the plane from the light source. The additional photo-receiver for the fluorescence radiation and the additional photo-receiver for the exciting radiation extend the testing of the paper for greater assurance.

Preferably, the light source, and the photo-receiver for the fluorescence radiation arranged on the other side of the plane, are arranged in such a manner that

the fields of irradiation and view coincide. In this case, the immediate emission of the fluorescence spectrum on excitation is measured. The arrangement may also be selected to be such that the fields of irradiation and view do not coincide. So that the two photo-receivers which are sensitive only to the fluorescence radiation may emit coincident signals, provision is made for the fields of view of these two photo-receivers to coincide. In order to obtain significant signals it is desirable that the fields of view of the light source and the photo-receiver comprise narrow strips extending preferably length-wise or width-wise and in particular over the entire length or width of the piece of paper.

The outputs of the photo-receivers are processed in a control unit. The control unit preferably includes a coincidence circuit, a counting circuit, a discriminator circuit and a trigger means. As most of the photo-senstive structural elements available on the market have too broad a band-width, the photo-receivers are composed of photo-sensitive structural elements and narrow-band type filters which allow to pass only the exciting emission and fluorescence emission spectrum, respectively.

If, in the proposed testing apparatus, differences in brightness are utilized to perform the testing operation, it is not necessary that an exact image be formed of the piece of paper on the sensitive surface of the photo-receiver. Photo-receivers useful for the measurement include semiconductor photo-cells, alkali metal photo-cells, or secondary emissive photo-multipliers.

The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a cross-sectional view of a bank-note with fluorescent fibres embedded therein;

Figure 2 is a cross-sectional view of a bank-note with fluorescent particles applied to the outer surface thereof;

Figure 3 is a perspective view of the apparatus embodying the invention;

Figure 4 is a side view of the apparatus embodying the invention and

Figure 5 is a block circuit diagram of the photo-receivers conencted with a control unit.

The testing process in accordance with the invention will now be described referring firstly to Figures 1 and 2. Fluorescent fibres F are incorporated in the bank-note B, the diameter of said fibres being almost as large as the thickness of the piece of paper constituting the bank-note B. The fibres may typically be 3 to 4 mm in length and the thickness of the fibres is not necessarily uniform. Assuming that, as shown in Figure 1, the exciting radiation AS is incident from above, a portion of this radiation is absorbed in the paper layer between the outer surface of the bank-note B and the surfaces of the individual fibres F. This layer is however so thin that the incident radiation AS excites the fluorescent fibres F to emit the fluorescence emission FS. The fluorescence emission FS is of longer wave length than ~~the~~ exciting radiation AS. This is indicated by the difference in sinuosity of the arrows of radiation although the difference in wave length need not be so considerable as the shown arrows suggest. The emitted fluorescence radiation FS passes through a small thicknes of paper in which only a small portion is absorbed. On both sides of the bank-note, therefore, a fluorescence radiation occurs under excitation by the exciting radiation AS.

This distribution of radiation cannot be detected in a bank-note such as that shown in Figure 2, which has its surface imprinted with fluorescent particles. Assuming firstly that within the bank-note of Figure 2 the exciting radiation is incident from above. The exciting radiation excites the particles P to emit the fluorescence radiation FS. This fluorescence radiation, however, can be observed only above the upper side of the paper, because the downwardly emitted fluorescence radiation FS is essentially absorbed in the body of the bank-note B. The space below the paper is therefore essentially free from fluorescence radiation. If in Figure 2 the exciting radiation impinges on the bank-note from below, it is absorbed in the body of the bank-note, so that the fluorescent particles P present on the upper side are not excited to emit the fluorescent spectrum. Nor is it possible to produce a state of fluorescent emission below the paper by increasing the thickness of the layer of fluorescent particles P in Figure 2, because the intrinsic brilliance of the fluorescent substances used cannot be increased *ad libitum* by increasing the volume of the applied layer, such increase merely leading to a saturation value.

In the apparatus shown in Figure 3, the bank-note B spread in a plane is passed between a light source 2 and a photo-receiver 3 by means of a suitable device 1. The device 1 comprises a pair of rubber belts 4a, 4b, 5a, 5b carrying the bank-note along its longitudinal edges and moving it in the direction of the arrow in Figures 3 and 4 while in its spread condition. The drive of the rubber belts 4a, 4b, 5a and 5b is not shown in detail. The invention is not restricted to this particular device for moving the bank-note past the light source and the photo-receiver; other devices may be used, such as glass plates placed one upon the other or vacuum gripping means or the like. A colour filter 6 is arranged

between the bank-note B and the light source 2, said colour filter being chosen to be of a very narrow bandwidth appropriate to the excitation spectrum required for the fluorescent substances used.

The photo-receiver 3 comprises a filter 7 and a photo-sensitive structural element 8. The filter 7 is selected to be of very narrow band-width appropriate to the spectrum of emission of the fluorescence particles used. The filter 7 may be omitted if the photo-sensitive structural element employed has itself a suitable narrow band characteristic. Another photo-receiver 9 is arranged on the same side of the bank-note B as the light source 2, said photo-receiver 9 comprising a filter 10 and a photo-sensitive structural element 11. The filter 10 is again selected to be of such narrow band-width that it allows only the fluorescence radiation FS to pass.

Below the bank-note B and in the path of the exciting radiation AS there is arranged a third photo-receiver 12 comprising a filter 13 and a photo-sensitive structural element 14. The filter 13 is selected to pass only the spectrum AS necessary for excitation.

It may be arranged, by suitable optical measures such as the fitting of diaphragms, that the fields of view of the lamp 2 and the photo-receivers 3, 9 and 12 embrace one and the same narrow srip over the entire width of the bank-note B. Alternatively the fields of view of the lamp 2 and the photo-receivers 3, 9 and 12 could embrace a narrow strip extending over the entire length of the bank-note.

The photo-receiver 3 is arranged to be inclined with respect to the plane of the bank-note to make room for the fitting of the photo-receiver 12, while the photo-receiver 9 at the other side of the bank-note is inclined so as not to interfere with the light source 2 and the filter 6. The filter 6 preferably allows only UV radiation to pass because, on the one hand, very many substances may be excited to fluoresce by UV radiation and, on the other hand, the transparency of paper in the UV spectral range is very low. The outputs of the photo-receivers 3, 11, 12 are connected with a control unit 19 via electric conductors 15, 16 and 17.

The block circuit diagram shown in Figure 5 represents the control unit 19 in connection with the photo-sensitive structural elements 8, 11 and 14. Respectively series-connected to each of the photo-sensitive structural elements in a preamplifier 20. The preamplifiers 20 respectively associated with the sensitive structural elements 8 and 11 are connected to a coincidence circuit 23 via lines 21 and 22, said coincidence circuit 23 being connected to a counting mechanism 25 via a line 24. The output of the counting mechanism 25 is connected to a trigger mechanism 27 via a line 26, an acceptance signal *a* or a rejection signal *z* appearing at the outputs of said trigger mechanism 27, which signals serve to operate electromagnetic devices diverting a rejected bank-note B from the conveyor path. Alternatively, the signals *a* and *z* may also be utilized to actuate optical or acoustic signalling devices. The preamplifier series-connected to the photo-sensitive structural element 14 is connected to an amplitude discriminator 29 via a line 28, the upper theshold O of which is adjustable through suitable means such as a rotary knob 30 and the lower threshold U of which is adjustable through suitable means such as a rotary knob 31. The output of the discriminator 29 is connected to the trigger mechanism 27 via a line 32.

The examination of the bank-note will now be described. If the bank-note is passed between the light source 2 and the photo-receiver 9 on the one side, and the photo-receivers 3 and 12 on the other side, the fibres incorporated in the bank-note successively enter the fields of view of the light source and the photo-receiver which fields of view, in the case of the embodiment shown, coincide. At the moment considered in Figures 3 and 4, the three fibres F are in the common field of view. At the outputs of the photo-receivers 3 and 9 there appear signals which are amplified in the pre-amplifiers 20 and checked as to their coincidence in the coincidence circuit 23. If coincident signals are present, then the output signal fed to the counting mechanism 25 via the line 24 switches the counting mechanism 25 onward by one unit. Such coincident signals occur several times, in relation to the number of fibres present, when the bank-note spread-out in a plane is passed through. When a predetermined minimum number is reached, an output signal appears at the output of a counting mechanism 25 provided with a preset arrangement which is passed to the trigger mechanism 27 via line 26.

Although the transparency of the bank-note paper is poor for the spectral range of the exciting radiation AS, the signal appearing at the output of the photo-element 14, after amplification by the pre-amplifier 20, is still required to have a minimum level, which is above the lower threshold U adjusted in the discriminator 29. Thus it is possible to recognise a type of paper having a wrong density. On the other hand, in the case of a crack or an inaccurate seam the exciting radiation passes through the filter 13 into the photo-element 14 with small reduction in intensity. The corresponding signal will thus be above the upper threshold O of the discriminator

29. The range of transparency of the discriminator 29 is adjusted to be such that cracks, inaccurate seams, lacking water marks or missing safety threads, wrong density of papers or areas of adhesion are recognised in the paper. If the signal applied via line 28 is above the upper threshold O or below the lower threshold U, a signal is supplied to the trigger mechanism 27 via line 32 which is effective to cause final rejection of the piece of paper tested as a bank-note.

By the method and apparatus of the invention it is possible to carry out a test for the authenticity of a piece of paper in a simple manner and without having to form on a photo-receiver an exact image of all the details of the piece of paper.

WHAT WE CLAIM IS:—

1. A method of testing the authenticity of pieces of paper containing fluorescent material, in which the paper is moved past a light source the radiation of which excites the fluorescent particles, and the fluorescence radiation emanating on that side of the paper which is averted from the light source is measured by means of a photo-receiver which is sensitive only to that radiation, the result of the test being indicated by the output of the photo-receiver.

2. A method in accordance with claim 1, wherein the fluorescence radiation emanating from that side of the paper which faces the light source is measured by means of a photo-receiver sensitive only to that radiation, the result of the test being indicated by the outputs of both of the photo-receivers.

3. A method in accordance with claim 1 or 2, wherein exciting radiation which passes through the paper is measured by means of a photo-receiver sensitive only to that exciting radiation, the output of which photo-receiver provides a further test result for the acceptance or rejection of the paper.

4. A method in accordance with any of claims 1 to 3, wherein signals derived from the fluorescence radiation emanating from that side of the paper which is averted from the light source are counted, the piece of paper passing the test provided with a predetermined minimum number of signals is reached.

5. A method in accordance with any of claims 2 to 4, wherein is measured the coincident occurrence of signals derived from the fluorescence radiation emanating from both sides of the paper.

6. A method in accordance with claim 5, wherein the coincident signals are counted, the piece of paper passing the test provided that a predetermined minimum number of signals is reached.

7. A method in accordance with any one of claims 1 to 6, wherein the received signals due to exciting radiation passing through the paper are discriminated, and rejection of the piece of paper indicated when the lower threshold is not reached or the upper threshold is exceeded.

8. A method in accordance with any one of claims 1 to 7, wherein the excitation and the registration of the radiation of fluorescence take place simultaneously.

9. A method in accordance with any one of the claims 1 to 3, wherein the excitation and the registration of the fluorescence radiation are effected at time intervals from each other.

10. Apparatus for testing the authenticity of pieces of paper containing fluorescent material, with the aid of a light source the radiation of which excites the fluorescent particles, and including means for moving the paper spread-out in a plane past the light source, the light source and a photo-receiver senstive to the fluorescence radiation emitted from the particles being arranged on opposite sides of the plane.

11. Testing apparatus in accordance with claim 10, wherein a second photo-receiver sensitive to the emitted fluorescence radiation is arranged on the light source side of the plane.

12. Testing apparatus in accordance with claim 10 or 11, wherein a photo-receiver sensitive to the exciting radiation is arranged on the side of the plane opposite that of the light source.

13. Testing apparatus in accordance with any one of claims 10 to 12, wherein the fields of view of the light source and the photo-receiver for fluorescence radiation arranged on the other side of the paper coincide.

14. Testing apparatus in accordance with any one of claims 10 to 13, wherein the fields of view of the two photo-receivers sensitive only to the fluorescence radiation coincidence.

15. Testing apparatus in accordance with any one of the claims 10 to 14, wherein the fields of view of light source and photo-receiver comprise narrow strips extending length-wise or width-wise of the paper.

16. Testing apparatus in accordance with any one of the claims 10 to 15, comprising a photo-receiver composed of photo-sensitive structural elements and narrow wave-band filters.

17. Testing apparatus in according with any one of claims 10 to 16, wherein a narrow band filter is arranged between the light source and the plane in which the paper is moved, said filter passing only the exciting radiation.

18. Testing apparatus in accordance with any one of claims 10 to 17, wherein

the outputs of the photo-receivers are connected via electric conductors to a control unit.

19. Testing apparatus in accordance with claim 18, wherein the control unit includes a coincidence circuit, a counting mechanism, a discriminator circuit and a trigger mechanism.

20. A method or apparatus for testing the authenticity of pieces of paper substantially as herein described with reference to the accompanying drawings.

ARTHUR R. DAVIES,
Chartered Patent Agents,
27, Imperial Square,
Cheltenham.
and
115, High Holborn,
London, W.C.1.
Agents for the Applicants.

Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon), Ltd.—1973.
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY
from which copies may be obtained.

Fig. 1

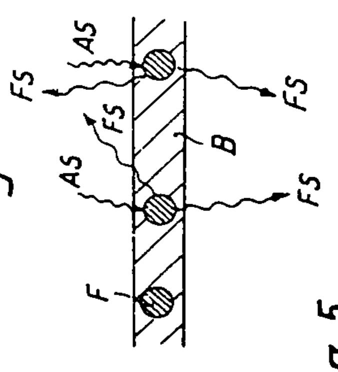


Fig. 2

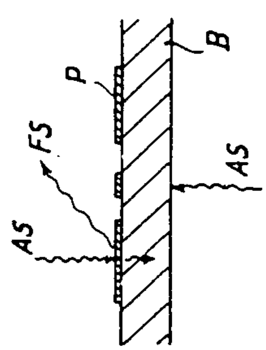


Fig. 5

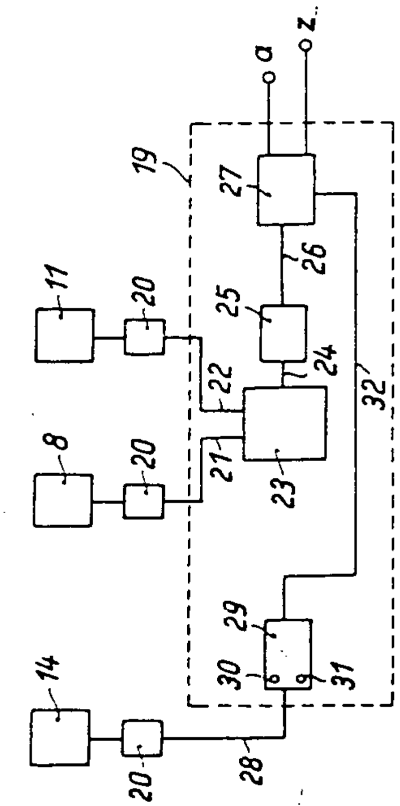


Fig. 3

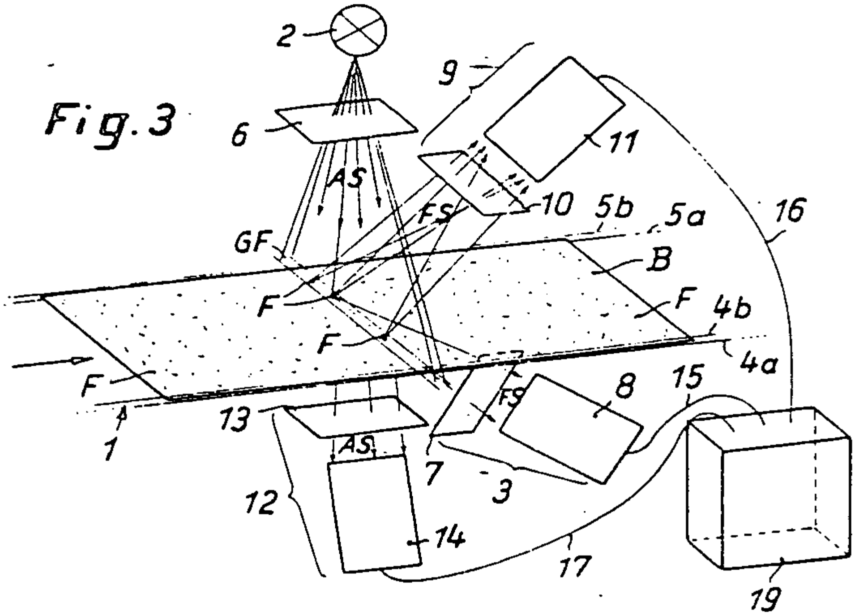
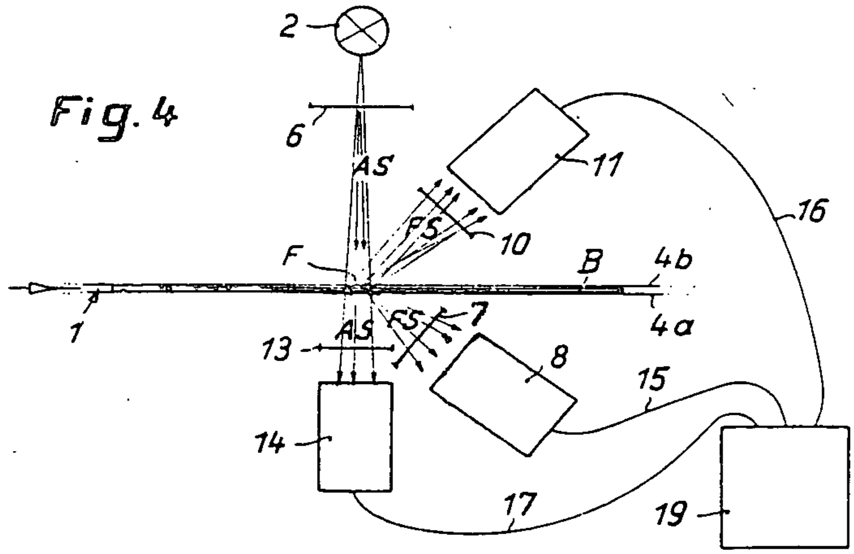

2
6
AS
9
11
10
FS
5b
5a
16
GF
B
F
F
4b
F
4a
F
15
8
13
FS
AS
1
7
3
12
14
17
19

Fig. 4


2
6
AS
11
16
FS
10
F
B
4b
1
4a
13
AS
FS
7
8
15
14
17
19